QUALITY ASSESSMENT OF DRINKING WATER IN FARIDABAD CITY AND APPLICATION OF BIOSORPTION TECHNOLOGY FOR REMOVAL OF HEAVY METAL CADMIUM IN WATER

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

to

Manav Rachna International Institute of Research and Studies
(Deemed to be University)

by

MEHAK VERMA
Registration number: 18/Ph.D/077

Under the supervision of
Dr. Sarita Sachdeva
Professor, Biotechnology
Faculty of Engineering and Technology

DEPARTMENT OF BIOTECHNOLOGY

FACULTY OF ENGINEERING & TECHNOLOGY

MANAV RACHNA INTERNATIONAL INSTITUTE OF RESEARCH & STUDIES

SECTOR-43, SURAJKUND –DELHI ROAD,FARIDABAD – 121001

JUNE, 2020

FACULTY OF ENGINEERING & TECHNOLOGY

Certificate

I hereby declare that the short synopsis entitled "**Quality Assessment Of Drinking Water In Faridabad City And Application Of Biosorption Technology For Removal Of Heavy Metal Cadmium In Water"**being submitted inpartial fulfillment of the requirement for the degree of Doctor of Philosophy in Biotechnology under Faculty of Engineering and Technology of Manav Rachna International Institute of Research & Studies, Faridabad during the Academic Year 2020-21.

It is a bona fide record of original work carried out under the supervision of Dr. Sarita Sachdeva and has not been submitted in full or part to any other university or institute for degree or diploma. Further, it is certified that short synopsis is plagiarism free and proof has been submitted.

Research Scholar: Mehak Verma
Registration No.:18/PhD/077

Supervisor:
Dr. Sarita Sachdeva
Professor, Biotechnology
Faculty of Engineering and Technology

(Chairman, DRC)

Chairperson, CDP

ABSTRACT

Scarce freshwater resource and its rapidly degrading quality whether from surface or groundwater,due to the discharge of untreated or noncompliant treated wastewater, leachates or dumping sites are the main compelling reason to adopt such technologies which ensure safe drinking water and are also can be adopted after modifications, by industries for treating their wastewater. In the recent years, excessive accumulation of contaminants especially heavy metal in water is a very critical and concerning issue, and affects water quality and safety. This is of great concern as safe drinking water is mandatory for healthy life . The increasing demand of water safety issues draws the attention towards the risk associated with contaminated drinking water. Present time scientific community is busy trying to find out as to what should be the percentage of treatment that must be put in place to achieve safety levels in an application to ensure well-being of one and all, be it public health or environment. Various techniques and methods have been employed to treat raw water for consumption on the basis of local needs of community but it is required to look for those tertiary treatment methods which are robust and yet cost effective.. The statutory bodies are focused on reuse of wastewater, but at the same timesafe drinking water supply is the essential requirement to masses. In the present study, attempts will be made to design an effective monitoring schedule for the examination of drinking water quality with good periodicity and attempts will also be made to inspect the ability of variousbiomaterialsfor the bio-sorption of heavy metalsin the household water supply system ofFaridabad.

Key words: Environment, Drinking water, Contamination, Heavy metal, Bio-sorption

CONTENTS

S. No.	Description	Page No.
1	Introduction	5-9
2	Literature Review	9-12
3	Description of Broad Area	12
4	Research Objectives	13
5	Research Methodology	13-14
6	Expected Outcome of the Research	14
7	References	15-22

1.0INTRODUCTION

Today, we have access to clean fresh water every day, the moment the tap is opened, it rushes into for use. Despite being vital for life forms and processes, water is extremely rare resource on this planet Earth and is not easily available to humans. On the whole 97% of this resource is saltwater and only 2.5% is freshwater and of this, more than two-third (68.7%) is frozen as ice and snow with one-third stored as groundwater. This reflects that 0.3% of the total freshwater on this terrene isactually available for use (***Gleick, P. H., 1996)*** Sustainable management of the water resources has gained immense importance at territorial and universal scales (**United Nations 2002; World Water Council, 2006**) to ensure availability of water for future generations and 'Integrated Water Resources Management' isthe major scientific paradigm because of its usefulnessin managingwater and other natural resources. Millennium Development Goals have included access to safe drinking water as a universal human right and extend support to achieve this (**United Nations Development Programme, 2006**).It is really remarkable thatsuch a small amount of water favours all the living species and the global population on this planet.

Water keeps moving in a system called "Hydro-geological Cycle" on this planet. Though the amount of absolute water has remained the same, the growing human settlements and the unequal distribution of water continue to create water availability and accessibility problems in number of countries and this for sure is going to impact their economic development.We all need clean and safe drinking water for a dignified and healthy life. When the amount of water withdrawn from the sources like rivers, lakes, streams or groundwater are in huge quantity and supply of water is not sufficient enough to satisfy all needs, be it human or that of ecosystem, it leads to water scarcity. This leads to increased competition between human beings, animals and other living organisms.At present, 2/5thof world's population is living in water stressed areas and it is projected that by 2025 it will rise to 50-65% which means, the number of people with no access to water maybe 3 billion, which certainly is a terrifying statistics for which a serious thought must be taken indeed.

Apparently, the requirement for water is going to rise inthe upcoming years and the main reason beingunsustainable and the surplususe of water worldwide. Also, another reason can be the decline inthe availability of surface water due to rise in variable pattern of rainfall and

decreased low flows in the snow dominating basins during summer. Climate change is another key factor which influences ground and surface water resources. There is very slight research onhow the climate change will make an impact on groundwater and will affect the relationship between the hydraulically connectedaquifers and surface waters (Alley, 2001).Climate change affect groundwater quality and quantity and it may also affect the recharge rates at the groundwater levels. Many studies have claimed that the climate change is one of the reasons for the shifts in spring recharges towards summer and winter recharge declines.It may also lead to agricultural changes with respect to crop production which also affect groundwater recharge and withinthe high latitude zone, thepermafrost begin to defrost which will cause dramatic fluctuations inthe levels of groundwater and its quality and it also contributes in global warming.

Groundwater is an important water resource for drinking, agricultural and industrial uses and is essential for our existence, but with passing time, anthropogenic activities has posed negative impacts on its quality**(Abollino et al. 2004)** and amongst the different variety of contaminants affecting water resources, heavy metals contamination is an important issue of concern considering their high toxicity, persistence & bioaccumulative nature**(Marcovecchio *et al.*, 2007)**. Potentially these toxicmetals are the group of elements with relatively high atomic density greater than 4 g/cm^3, or 5 times or more, greater than water **(Hawkes 1997).** Mercury, cadmium, arsenic, chromium, lead, thallium are some of the examples of such heavy metals. Although, some of these heavy metals are necessary for the health of human beings but surplus amount of these toxic metals can cause negative effects on the human body and may induce cancer and other diseases **(USEPA, 2015).** It is a well known fact that water is an important necessity for our lives and with the advancement of technologies and economic development; water resources all over the world are threatened and many scientists in the recent years have reported the contamination by these toxic metals with an increase in human exposure.

Metal ions find their path to human body via water and are found interacting with the Cell Organelles such as Mitochondria, Endoplasmic Reticulum(ER), Cell Membrane and even cell components such as Deoxyribonucleic Acid, changes in DNA, organ failure and severe health problems **(Tchounwou et al., 2012)**.Studies have found that an adult human being can

absorb 40-50% of lead(Pb) through drinking water and for children, the absorption rates are found greater than 50% **(Flora et al., 2006).**Industrial pollution, off-gassing from the earth's crust is the natural ways through which mercury enters in the water. Further, it enters through the food chain via aquatic animals such as fish and finally enters into the humans**(Wise et al., 1993).**There areseveral reports suggesting a strong link between metal exposure and high risk of deadly health hazards **(Tchounwou et al., 2002)**.So, it is of utmost importantance to determine the present quality of groundwater to know its suitability for drinking, agricultural and domestic purposes.

Ground water is the major source of drinking water in many countries and it is affected by arsenic and fluoride pollution in several parts of India due to the natural and anthropogenic pollutions **(CGWB, 2010).**Water Scarcity has emerged as one of the greatest concern issues in manyparts of India such as Jharkhand, West Bengal, Orissa, Andhra Pradesh, Western Uttar Pradesh, Punjab and Rajasthan (**Tiwari & Singh 2014**). Faridabad district of Haryana is also found affected by water contamination and is found to be marred on water crisis. It is considered as one of the most polluted city in India and certain areas are notified as water stressed by Central Ground Water Board **(CGWB).**The city is also referred as the Industrial centre of the state with 12,468 industries and is famous for Henna production. Several industries are in red zone and contribute in polluting the city. The different industries include Chemicals, Electroplating, Hospitals, Automobile Components, Crane & lift manufacturing,Iron &Steel,Tyre Manufacturing, Textile Dyeing and Power Station which generates enormous amount of effluent.These effluents are being treated in the treatment plants and are further discharged into the Yamuna river; synchronously other part of this effluent is not given proper secondary treatment and is discharged to the open drains namely; Gaunchi Drain and Buria Nala and finally it reaches to River Yamuna. This untreated discharge coming from domestic and industrial areas are the main cause of contamination of ground water in the area **(Rosin et al., 2013, Haryana pollution control board, 2011).**

Faridabad is the most densely populated district of Haryana state and is the major industrial area. The geographic area of the city is 742.90 sq km and accommodates a population of 18, 09,733 (Census figures, 2011) with total number of 40 wards.It has an elevation of 198 meters (649 ft) approximately. It is about 25 Kilometers from Delhi in 28^{o} 10' 50" North

Latitude and 77º 33' 23" East Longitude. It is surrounded by Delhi (NCT) on its North, Palwal District on the South, Gurugram District on the West and State of Uttar Pradesh on its East. The District Boundary located on its eastern side is separated by River Yamuna with UP State. As the water demands are rising with the increase in population rate, it's becoming more important to look after the solution to save the natural resources.

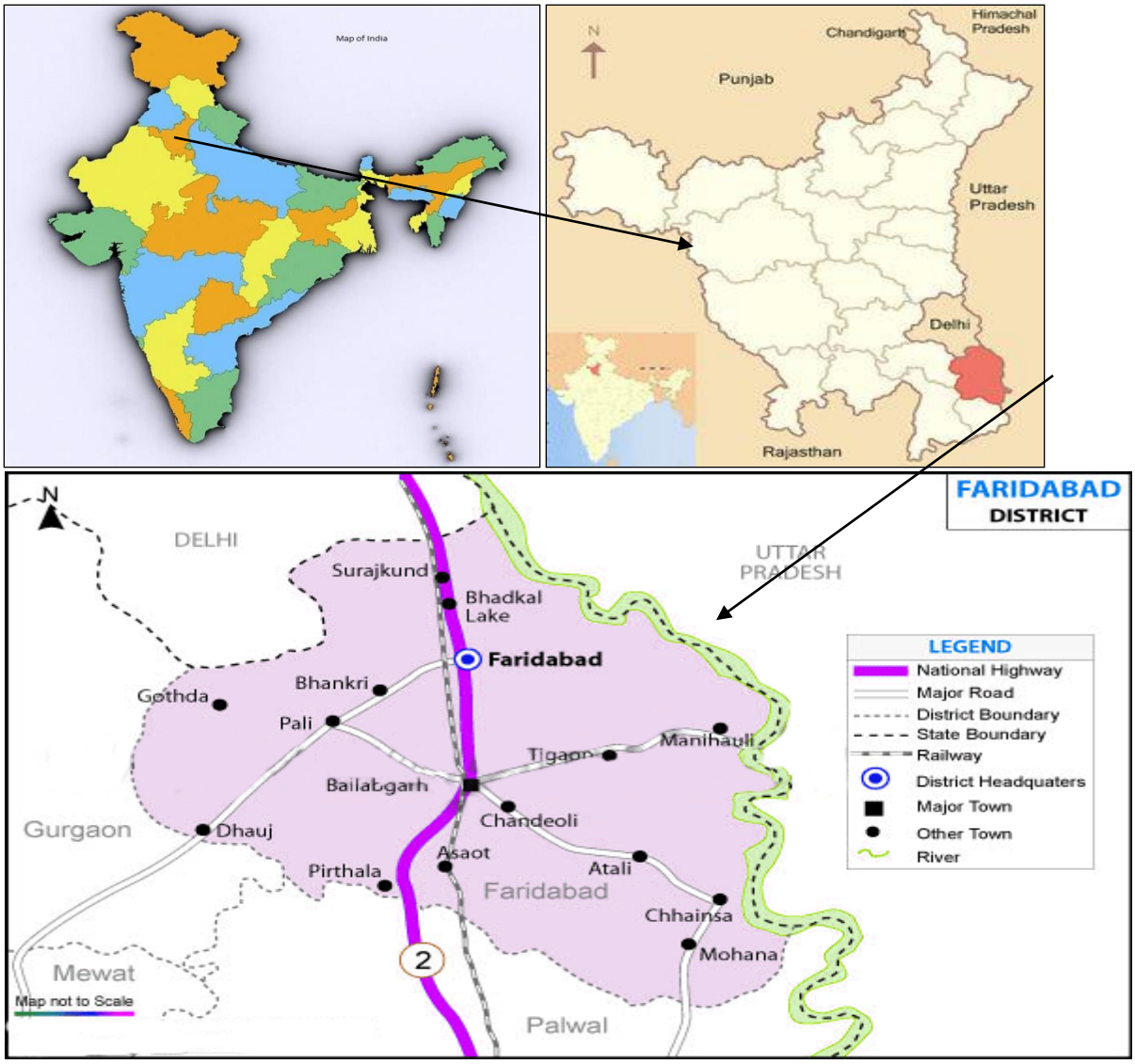


Figure 1: Map of the study area-Faridabad, Haryana, India(Source: https://tinyurl.com/y3jwbu6j)

Ground water in the district occurs in alluvium and the underlying weathered quartzite. The shallow groundwater of the area is alkaline and moderately to highly saline in nature **(CGWA).**Faridabad is staring at water crisis in future due to a lack of proper management of its water resources. Due to numerous industries and bothersome garbage disposal

technologies, groundwater contamination is rapidly taking place at an alarming rate in districts of Haryana including Faridabad, which is a big problem for National Capital Region.

2.0LITERATURE REVIEW

Water Scarcity has emerged as one of the greatest concern issues in many parts of India such as Jharkhand, West Bengal, Andhra Pradesh, Uttar Pradesh, Punjab, Rajasthan and Orissa **(Tiwari & Singh 2014).** Due to the increase in mining activities, which started decades back in India, leachates generated from industrial waste affect the quality of groundwater **(Khan et al., 2005)** which may include heavy metals. Heavy metal toxicity to aquatic organisms and humans has been a topic of concern for scientists for many years. In a study conducted by **Low and Lee, 1991** it was found that thereare different sources of pollutants in water bodies but the industrial effluents is one of the major sources of heavy metal pollution and the toxic metals such as Zinc, Cadmium, Chromium, Copper, and Lead find their ways to the industries as nickel batteries, metal plating industries, as stabilizers of alloys and pigments.**Rajnakar et al., 2009** determined the Water quality index using the Water Quality Index calculator which was invented by the National Sanitation Foundation (NSF) information system and the nutrients in water were determined by spectrophotometer (Spectronic, Genesys-2). The Water Quality Index calculated for the study observe the range of water samples in the post-monsoon which was found out to be 61, 52.5,49 for bore well, dug well and hand pump, in summers it was 60.5, 55.4, 57.5 and the WQI in winters was found to be 62.5,61 and 66.25 for the same. Also, **Momodu and Anyakora, 2010** analyzed the heavy metals present in the water samples which were collected from the proximity of Surulere, Lagos. Presence of heavy metals like aluminum, cadmium and lead were analyzed using an Atomic Absorption Spectrophotometer (buck scientific 210VGP AAS).Forty nine water samples were collected from well & borehole and their levels of contaminant were compared with maximum contamination level specified by WHO. The maximum contamination level for cadmium, aluminium or lead was found to be 0.003, 0.01 and 0.2 mg/L. The result obtained from the water analysis showed that aluminium was not exceeding the maximum contamination level. However, cadmium and lead concentration were found above the contamination level.**Muhammad et al., 2011** investigated the concentration of

heavy metals in drinking water (surface water and groundwater) sample and The Hazard Quotient (HQ) and Chronic Daily Intake (CDI) of the heavy metals were calculated where the value of zinc was found highest. A survey was undertaken on the soils, farming practices and sub-surface irrigation water of the 30 villages of Faridabad city by **Rosin et al., 2013.** The study revealed that the area was found to be alkaline in nature with EC_{mean} = 4.79-2.76 dS/m, F_{mean} = 11.57-4.83 ppm and Cl_{mean} = 2043.30-457.26 ppm. Water-soluble concentrations of the soil-root zone of some metals such as chromium were found 0.06 ±0.00 ppm, nickel: 0.02±0.01 ppm, and lead: 0.05±0.01 ppm and are subjected to threats for percolating water. Further,**Giri and Singh, 2015**investigated samples for assessment of health risks associated with heavy metals found in the drinking water of the study site. The largest risk contributing metals was manganese, cobalt, and arsenic. The notable outcome of four factors under Principal component analysis (PCA) showed 84.99 % of the variance with >1 initial Eigen value.The hazard index (HI) varied from 0.15 to 9.71 for children and 0.18 to 11.34 for adults respectively. Hazard index less than 1 indicates a potential for the effect on human health.

Water modelling of the Faridabad district was done by **Rahman, Arpan and Jafri**, **2016**. And certain areas of the districts are notified as water stressed by Central Ground Water Board **(CGWB)**.Hydrographs studies showed that there are certain distinct patterns in hydrographs behavior. In areas such as Bhopani and Ballabgarh, the water level is found decreasing and the western areas of the city will face severe water shortage in the coming years. The areas include Bajri, Banker, Jaipur, Gujrat, Nagla, Faridabad, Fatehpur, Sirohi, Tiruppur, Dhoj, Tikri, Palampur, Zahopur and Awalpur and the results revealed that the increase in groundwater draft will strongly affect the availability of groundwater resources.Heavy metal pollution in River Yamuna was studied by **Pal et al., 2018.** The Dissolved Oxygen of the river water ranged between 5 - 6 mg/L during summers and 5.8 - 9 mg/L during post-rainy seasons and the BOD ranged between 10 - 30 mg/L in summers and it decreased in the post rainy season and ranged between 2 - 23 mg/L. The mean Heavy Metal Pollution Index (HPI) for the study was calculated and found to be 1534 and it decreased to 412 in rainy seasons. The overall HPI for River Yamuna was 973 which were found to be higher than the critical value of 100Pollution in water bodies is the major cause of the deterioration of quality water. Human activities are the primary source of water

pollution due to industrialization and developmental activities. The Water Quality Index for Malin River was calculated and was found to be 134.4260 by **Bhutiani et al., 2018**which clearly indicatesabout the deteriorating quality of water in the area.

Groundwater contamination is a very critical and concerning issue, once an aquifer becomes contaminated; it becomes very problematic, expensive and time consuming to clean it **(Tiwari et al., 2015).** Here, remediation of contaminated groundwater becomes very important to ensure safe drinking water. Several methods are used for the removal of heavy metals all over the world such as ion exchange method, membrane technologies, solvent extraction,electrochemical treatment, complexation, foam floatation, coagulation, activated carbon adsorption, cementation and chemical precipitation**(Peter et al., 1985,Rao et al., 2010).**Different treatment technologies for the removal of heavy metals were classified into three main categories: chemical treatment, biological, or biosorptive treatment and physico-chemical treatment (**Hashim et al., 2011).**Biosorptive treatment utilizes low cost dead biomass to sequester toxic metals from industrial effluents. The process involves a solid phase which is referred as a sorbent and a liquid phase called as a solvent comprised of a dissolved species to be sorbed that is a metal ion **Kratochvil and Volesky, 1998.**Investigation of alginate was observed by **Fourest and Volesky, 1997** in 4 varieties of brown sea weeds namely *Ascophyllum nodosum, Sargassum fluitans, Laminaria japonica and Fucus vesiculo-sus.* The alginate content of these 4 varieties of sea weed was observed to be in high amountsand was determined using potentiometric titration, 13C-nuclear magnetic resonance (NMR), viscosity measurements and chemical analysis.From the 4 varieties, *Sargassumfluitans* was considered as the most suitable algal biosorbent for the removal of metals. The status of biomass living or non living, biomass concentration, pH, temperature, ionic strength & presence of various metal ions in the solution are some of the major factors by which the biosorption of toxic metals gets affected**(Das et al., 2008 ,Esposito et al., 2001).**A gram negative bacterium *Spherotilus natans* was taken as the biosorbent material for the removal of metals such as copper and cadmium from the aqueous solutions. The results showed both the toxic metals were adsorbed and the metals biosorption extent was repressed by decrease in pH(**Esposito et al., 2001).**Many studies have revealed the use and advantages of Alginate biopolymer in cell immobilization studies. Biocompatibility, easy gelationand ability to retain cells in its matrix pores are some of the advantages of the alginate

biopolymer**(Al-Rub et al., 2004).**Biosorption of heavy metals such as cadmium, copper, zinc, nickel and lead using various types of algae was studied by**Romera et al., 2007** .The various algae used in the sorption study include *Asparagopsis armata, Codium vermilara, Spirogyra insignis, Ascophyllum nodosus and Chondrus crispusand Fucus spiralis* and the best result was obtained with lowest biomass concentration that is 0.5g/L by the brown algae *Fucus spiralis.* Biopolymers made from algae are found to be efficient, inexpensive, and safeandtherefore, they are really competitive with activated carbon and ion exchange methods for the removal of heavy metalfrom the aqueous medium**(Yunus and Kargi, 2009)**.Calcium alginate beads are also found to be very efficient biosorbing material for the removal of copper from water (**Singh et al., 2012).**Biosorption is considered as a useful replacement to conventional systems for the removal of heavy metals from industrial water**Veglio and Beolchini, 1997.**

3.0DESCRIPTION OF BROAD AREA

The increase in urbanization has intensate the environmental pollution and is resulting in degradation of natural resources with increased number of pollutants in the environment.As the pollution is surging with a great speed, it'svery important to look after natural resources and find a way for sustainable development. These days, contamination in ground water is aforeshadowed issue in the environment. Most of the population in the world is dependent on groundwater for drinking, agricultural and irrigational purposes. Polluted water comes as defilement on water safety issues, especially when it's contaminated through heavy metals which find their way to groundwater by landfill leachates, seepage from industrial spills, sewage or from deep well disposal of liquid waste. There is a great need for adoption ofbiosorption technologies to manage the contaminated groundwater and ensure safe drinking water for future needs and demand.With this view, the present investigation will be undertaken to find out the current quality status of groundwater supplied for drinking purpose to Faridabad and suitable quick method for the biosorption of heavy metals.

4.0 RESEARCH OBJECTIVES

1. To study the household water supply system of Faridabad City.
2. To access the drinking water quality on seasonal basis from Ranney wells.
3. To access the drinking water quality on seasonal basis from Tube-wells.
4. To access the presence and quantum of Heavy Metals in Drinking Water Supply.
5. To estimate the Biosorption potential of selected biomaterial for heavy metal removal from extracted Groundwater.

5.0 RESEARCH METHODOLOGY

1. **Study of Water supply system in Faridabad.**

   The Ranney well and Tube well, water supply system of Faridabad will be observed and studied.

   The source to end point will be taken into account for all network of drinking water supply of District of Faridabad.

2. **Estimation of Characteristics of Water from Ranney Wells**

   For this, physico-chemical analysis and heavy metal profiling of household water supply of the Faridabad city would be studied on seasonal basis from Ranney wells using the Standard Methods recommended by American Public Health Association (APHA, 1985)

3. **Estimation of heavy metals in water of Ranney Wells and Tube wells**

   The profile of heavy metals in water of collected samples will be studied. The standard method for sampling as well as estimation will be followed as per APHA guidelines (1985).

4. **Estimation of the Biosorption potential of algae for heavy metal removal**

   (i) Biomasscharacterizationwould be conducted using Fourier transform infrared spectroscopy (FTIR) for identification of various functional groups.

   (ii) Morphological examination of algae would be conducted using scanning electron (SEM) microscope.

(iii) The elemental compositions of the algal biosorbant would be examined by elemental analyzer. The percentage (%) of carbon (C), Nitrogen (N), Hydrogen (H) and oxygen (O) in the sample will be determined accordingly.

(iv) The Total ash content, surface area and density analysis of algal bioadsorbant would be estimated.

(v) The effect of various parameters on adsorption of metal on algal bio-adsorbent would be studiedie: pH, dosage, contact time, temperature and initial metal concentration using synthetic water and real drinking water.

(vi) Biochemical characterization of biosorbent before and after biosorption.

(vii) To evaluate the mechanism of biosorption in the selectedalgae using adsorption isotherm.

(viii) The re-cyclability and desorption studies would be conducted subject to availability of facilities and time frame

6.0OUTCOME OF THE RESEARCH

Deteriorating quality of water especially due to heavy metals has become a major concern issue for the human health and environment. Human body absorbs a number of elements from drinking water some of which can be essential and some can be toxic like heavy metals. They are generally referred as naturally occurring metals with relatively high densities, atomic weight and atomic number. Mercury, cadmium, arsenic, chromium, thallium, lead are some of the examples of heavy metals. Heavy metal contamination in water leads to accumulation of metal ions in the body that is hazardous and varies from species to species depending on their uptake. Accumulation of these heavy metals in water through natural and anthropogenic activities, may affect water quality and thereupon safety to human beings.Therefore, it's very important to find suitable techniques to address this emerging issue. Though, there are number of tools and methods for the removal of these toxic metal ions from water but scientist throughout the world are focused on new cost effective techniques for heavy metals removal and are directing towards biosorption potential. Algae are used as the metal biosorbent and are proved to be potential in decreasing the metal ion concentration from the aqueous solutions.

The present research is undertaken on the assessment of drinking water quality and estimation of heavy metals in drinking water in District Faridabad with the aim of finding suitablebiomass for removal of toxic metalsfrom drinking water by biosorption.

7.0 REFERENCES

- Abollino, A., Aceto, M., Buoso, S., Gasparon, M., Green, W. J., Malandrino, M., et al. (2004). Distribution of major, minor and trace elements in lake environments of Antarctica. Antarctic Science, 16(3), 277–291.
- Acharya, S., Sharma, S.K. and Khandegar, V., 2018. Assessment of groundwater quality by water quality indices for irrigation and drinking in South West Delhi, India. *Data in brief*, *18*, p.2019.
- Action Plan For Abatement of Pollution in respect of Faridabad Town. Haryana State Pollution Control Board, Haryana, India. 2010-2011.
- Adefemi, S.O. and Awokunmi, E.E., 2010. Determination of physico-chemical parameters and heavy metals in water samples from Itaogbolu area of Ondo-State, Nigeria. *African Journal of Environmental Science and Technology*, *4*(3).
- Alley, W.M., 2001. Ground water and climate. *Ground Water*, *39*(2), pp.161-161.
- Al-Rub, F.A., El-Naas, M.H., Benyahia, F. and Ashour, I., 2004. Biosorption of nickel on blank alginate beads, free and immobilized algal cells. *Process Biochemistry*, *39*(11), pp.1767-1773.
- Annadurai, G., Juang, R.S. and Lee, D.J., 2003. Adsorption of heavy metals from water using banana and orange peels. *Water science and technology*, *47*(1), pp.185-190.
- Avvannavar, S.M. and Shrihari, S., 2008. Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India. *Environmental Monitoring and Assessment*, *143*(1-3), pp.279-290.
- Bhutiani, R., Varun, A.F.T. and Khushi, R., 2018. Evaluation of water quality of River Malin using water quality index (WQI) at Najibabad, Bijnor (UP) India. *Environment Conservation Journal*, *19*(1&2), pp.191-201.

- Central Ground Water Board: Dynamic Ground Water, Resources of India, March 2011.
- Das, N., Vimala, R. and Karthika, P., 2008. Biosorption of heavy metals–an overview.
- Duruibe, J.O., Ogwuegbu, M.O.C. and Egwurugwu, J.N., 2007. Heavy metal pollution and human biotoxic effects. *International Journal of physical sciences*, *2*(5), pp.112-118.
- Esposito, A., Pagnanelli, F., Lodi, A., Solisio, C. and Veglio, F., 2001. Biosorption of heavy metals by Sphaerotilus natans: an equilibrium study at different pH and biomass concentrations. *Hydrometallurgy*, *60*(2), pp.129-141.
- Flora, S.J.S., Flora, G. and Saxena, G., 2006. Environmental occurrence, health effects and management of lead poisoning. Lead Chemistry, Analytical Aspects, Environmental Impacts and Health Effects.
- Fourest, E. and Volesky, B., 1997. Alginate properties and heavy metal biosorption by marine algae. *Applied Biochemistry and Biotechnology*, *67*(3), pp.215-226.
- Gebrehiwot, A.B., Tadesse, N. and Jigar, E., 2011. Application of water quality index to assess suitablity of groundwater quality for drinking purposes in Hantebet watershed, Tigray, Northern Ethiopia. *ISABB Journal of Food and Agricultural Sciences*, *1*(1), pp.22-30.
- Giri, S. and Singh, A.K., 2015. Human health risk assessment via drinking water pathway due to metal contamination in the groundwater of Subarnarekha River Basin, India. *Environmental monitoring and assessment*, *187*(3), p.63.
- Gleick, P.H., 1996. Water resources. *Encyclopedia of climate, weather*, pp.817-823.
- Ground Water Scenario of India 2009-10. Central Ground Water Board Ministry of Water Resources Government of India, Faridabad, 2010.
- Gupta, R. and Misra, A.K., 2018. Groundwater quality analysis of quaternary aquifers in Jhajjar District, Haryana, India: Focus on groundwater fluoride and health implications. *Alexandria engineering journal*, *57*(1), pp.375-381.
- Harris, P.O., Ramelow, G.J., 1990. Binding of metal ions by particulate biomass derived from Chlorella vulgaris and Scenedesmus quadricauda. Environ. Sci. Technol. 24, 220–228. Iskandar, L.N., Izzati, A.N

- Hashim, M.A., Mukhopadhyay, S., Sahu, J.N. and Sengupta, B., 2011. Remediation technologies for heavy metal contaminated groundwater. *Journal of environmental management*, *92*(10), pp.2355-2388.
- Hawkes JS (1997) Heavy metals. J Chem Edu 74:1369–1374
- Hinrichsen, D. and Tacio, H., 2002. The coming freshwater crisis is already here. *The linkages between population and water. Washington, DC: Woodrow Wilson International Center for Scholars*, pp.1-26.
- Ivanov V., Hung YT. (2010) Applications of Environmental Biotechnology. In: Wang L., Ivanov V., Tay JH. (eds) Environmental Biotechnology. Handbook of Environmental Engineering, vol 10. Humana Press, Totowa, NJ
- Jain, C.K., Bandyopadhyay, A. and Bhadra, A., 2010. Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. *Environmental monitoring and assessment*, *166*(1-4), pp.663-676.
- Kratochvil, D. and Volesky, B., 1998. Advances in the biosorption of heavy metals. *Trends in biotechnology*, *16*(7), pp.291-300.
- Lesmana, S.O., Febriana, N., Soetaredjo, F.E., Sunarso, J. and Ismadji, S., 2009. Studies on potential applications of biomass for the separation of heavy metals from water and wastewater. *Biochemical Engineering Journal*, *44*(1), pp.19-41.
- Logeshkumaran, A., Magesh, N.S., Godson, P.S. and Chandrasekar, N., 2015. Hydro-geochemistry and application of water quality index (WQI) for groundwater quality assessment, Anna Nagar, part of Chennai City, Tamil Nadu, India. *Applied Water Science*, *5*(4), pp.335-343.
- Mandina, S., Chigondo, F., Shumba, M., Nyamunda, B.C. and Sebata, E., 2013. Removal of chromium (VI) from aqueous solution using chemically modified orange (citrus cinensis) peel. *J. Appl. Chem*, *6*(2), pp.66-75.
- Marcovecchio, J.E., S.E. Botte and R.H. Freije, 2007. Heavy Metals, Major Metals, Trace Elements. In: Handbook of Water Analysis. L.M. Nollet, (Ed.). 2nd Edn. London: CRC Press, pp: 275-311.
- Mohan, S.V., Nithila, P. and Reddy, S.J., 1996. Estimation of heavy metals in drinking water and development of heavy metal pollution index. *Journal of Environmental Science & Health Part A*, *31*(2), pp.283-289.

- Momodu, M.A. and Anyakora, C.A., 2010. Heavy metal contamination of ground water: The Surulere case study. *Res J Environ Earth Sci*, *2*(1), pp.39-43.
- Muhammad, S., Shah, M.T. and Khan, S., 2011. Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. *Microchemical journal*, *98*(2), pp.334-343.
- Mulligan, C.N., Yong, R.N. and Gibbs, B.F., 2001. Remediation technologies for metal-contaminated soils and groundwater: an evaluation. *Engineering geology*, *60*(1-4), pp.193-207.
- Pal, R., Dubey, R.K., Dubey, S.K., Singh, A.K. and Nitant, A.K., 2018. Assessment of heavy metal and organic pollution in Yamuna river at Etawah district of Uttar Pradesh. *Int. J. Chem. Stud.*, *6*, pp.399-402.
- Parga, J.R., Cocke, D.L., Valenzuela, J.L., Gomes, J.A., Kesmez, M., Irwin, G., Moreno, H. and Weir, M., 2005. Arsenic removal via electrocoagulation from heavy metal contaminated groundwater in La Comarca Lagunera Mexico. *Journal of hazardous materials*, *124*(1-3), pp.247-254.
- Park, D., Yun, Y.S. and Park, J.M., 2010. The past, present, and future trends of biosorption. *Biotechnology and Bioprocess Engineering*, *15*(1), pp.86-102.
- Peters, R.W., Ku, Y. and Bhattacharyya, D., 1985, September. Evaluation of recent treatment techniques for removal of heavy metals from industrial wastewaters. In *AICHE symposium series* (Vol. 81, No. 243, pp. 165-203). Citeseer.
- Petrović, M., Gonzalez, S. and Barceló, D., 2003. Analysis and removal of emerging contaminants in wastewater and drinking water. *TrAC Trends in Analytical Chemistry*, *22*(10), pp.685-696.
- Prasad, B., Kumari, P., Bano, S. and Kumari, S., 2014. Ground water quality evaluation near mining area and development of heavy metal pollution index. *Applied water science*, *4*(1), pp.11-17.
- Rahmanian, N., Ali, S.H.B., Homayoonfard, M., Ali, N.J., Rehan, M., Sadef, Y. and Nizami, A.S., 2015. Analysis of physiochemical parameters to evaluate the drinking water quality in the State of Perak, Malaysia. *Journal of Chemistry*, *2015*.

- Rajankar, P.N., Gulhane, S.R., Tambekar, D.H., Ramteke, D.S. and Wate, S.R., 2009. Water quality assessment of groundwater resources in Nagpur Region (India) based on WQI. *Journal of chemistry*, *6*(3), pp.905-908.
- Rajput, S. and Shekhar, S., Evaluation and Characterization of Saline Groundwater in Context of Geogenic Sources in Faridabad District of Haryana. *METHODOLOGY*, *2*, p.3.
- Ramakrishnaiah, C.R., Sadashivaiah, C. and Ranganna, G., 2009. Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. *Journal of Chemistry*, *6*(2), pp.523-530.
- Rao, K.S., Mohapatra, M., Anand, S. and Venkateswarlu, P., 2010. Review on cadmium removal from aqueous solutions. *International journal of engineering, science and technology*, *2*(7).
- Rathinam, A., Maharshi, B., Janardhanan, S.K., Jonnalagadda, R.R. and Nair, B.U., 2010. Biosorption of cadmium metal ion from simulated wastewaters using Hypnea valentiae biomass: A kinetic and thermodynamic study. *Bioresource technology*, *101*(5), pp.1466-1470.
- Reddy, D.H.K., Ramana, D.K.V., Seshaiah, K. and Reddy, A.V.R., 2011. Biosorption of Ni (II) from aqueous phase by Moringa oleifera bark, a low cost biosorbent. *Desalination*, *268*(1-3), pp.150-157.
- Reza, R.; Singh, G., (2010). Assessment of heavy metal contamination and its indexing approach for river water. Int. J. Environ. Sci. Tech., 7 (4), 785-792.
- Romera, E., González, F., Ballester, A., Blázquez, M.L. and Munoz, J.A., 2007. Comparative study of biosorption of heavy metals using different types of algae. *Bioresource technology*, *98*(17), pp.3344-3353.
- Rosin, K.G., Kaur, R., Singh, S.D., Singh, P. and Dubey, D.S., 2013. Groundwater vulnerability to contaminated irrigation waters-A case of peri-urban agricultural lands around an industrial district of Haryana, India. *Procedia Environmental Sciences*, *18*, pp.200-210.
- Saeedi, M., Abessi, O., Sharifi, F. and Meraji, H., 2010. Development of groundwater quality index. *Environmental monitoring and assessment*, *163*(1-4), pp.327-335.

- Saxena, A., Bhardwaj, M., Allen, T., Kumar, S. and Sahney, R., 2017. Adsorption of heavy metals from wastewater using agricultural–industrial wastes as biosorbents. *Water Science*, *31*(2), pp.189-197.
- Scragg, A.H., 2005. *Environmental biotechnology*. New York: OXFORD university press.
- Sharma, D. and Kansal, A., 2011. Current condition of the Yamuna River: An overview of flow, pollution load, and human use. *Yamuna River: A confluence of waters, a crisis of need*.
- Sharma, D. and Kansal, A., 2011. Water quality analysis of River Yamuna using water quality index in the national capital territory, India (2000–2009). *Applied water science*, *1*(3-4), pp.147-157.
- Sherring, Arpan & Rahman, Thamar & JAFRI MD, AHSAN. (2016). GROUND WATER MODELING OF FARIDABAD DISTRICT, HARYANA, INDIA. International Journal of Agriculture Sciences. Volume 8. 1957-196.
- Singh, L., Pavankumar, A.R., Lakshmanan, R. and Rajarao, G.K., 2012. Effective removal of Cu2+ ions from aqueous medium using alginate as biosorbent. *Ecological engineering*, *38*(1), pp.119-124.
- Smith, A.H., Lingas, E.O. and Rahman, M., 2000. Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. *Bulletin of the World Health Organization*, *78*, pp.1093-1103.
- Tchounwou, P.B., Wilson, B.A., Abdelghani, A.A., Ishaque, A.B. and Patlolla, A.K., 2002. Differential cytotoxicity and gene expression in human liver carcinoma (HepG2) cells exposed to arsenic trioxide, and monosodium acid methanearsonate (MSMA). *International Journal of Molecular Sciences*, *3*(11), pp.1117-1132.
- Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K. and Sutton, D.J., 2012. Heavy metal toxicity and the environment. In *Molecular, clinical and environmental toxicology* (pp. 133-164). Springer, Basel.
- Tiwari, M., Shukla, N.K., Kumar, V., Sharma, G.D., Gupta, M.K., Singh, A., Toppo, P. and Tiwari, M.K., 2015. Assessment of ground water quality of Hamirpur District, Uttar Pradesh, India. *Intern. J. Current Micro. Appl. Sci*, *4*(1), pp.597-603.

- UNDP, 2006,MDG Targets and Indicators [accessed 06.03.07: http://www.undp.org/mdg/goallist.shtml]
- United Nations 2006, World Water Development Report 2: Water, a shared responsibility. UNESCO, Paris, 601 pp.
- United Nations Committee on Economic, Social and Cultural Rights, 2003, General Comment No. 15 (2002). The Right to Water. E/C.12/2002/11, United Nations Social and Economic Council, 18 pp
- United Nations, 2002, Johannesburg Plan of Implementation of the World Summit on Sustainable Development. United Nations, 72 pp
- Ur Rehman, S., Hussain, Z., Zafar, S., Ullah, H., Badshah, S., Ahmad, S.S. and Saleem, J., 2018. Assessment of Ground Water Quality of Dera Ismail Khan, Pakistan, Using Multivariate Statistical Approach. *Science*, *37*(4), pp.173-183.
- Veglio, F. and Beolchini, F., 1997. Removal of metals by biosorption: a review. *Hydrometallurgy*, *44*(3), pp.301-316.
- Vodela, J.K., J.A. Renden, S.D. Lenz, W.H. Mchel Henney and B.W. Kemppainen, 1997. Drinking water contaminants. Poult. Sci., 76: 1474-1492.
- Volesky, B. and Holan, Z.R., 1995. Biosorption of heavy metals. *Biotechnology progress*, *11*(3), pp.235-250.
- Wehrheim, B., Wettern, M., 1994. Biosorption of cadmium, copper and lead by isolated mother cell walls and whole cells of Chlorella fusca. Appl. Microbiol. Biotechnol. 41, 725–728.
- WHO (World Health Organization), 2011. Guidelines for Drinking-water Quality. fourth ed. World Health Organization, Geneva.
- Wise, J.P., Orenstein, J.M. and Patierno, S.R., 1993. Inhibition of lead chromate clastogenesis by ascorbate: relationship to particle dissolution and uptake. *Carcinogenesis*, *14*(3), pp.429-434.
- Wongsasuluk, P., Chotpantarat, S., Siriwong, W. and Robson, M., 2014. Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. *Environmental geochemistry and health*, *36*(1), pp.169-182.

- World Water Council, 2006, Final Report of the 4th World Water Forum. National Water Commission of Mexico, Mexico City, 262 pp
- YADAV, A. and SEN, A., RE-INVENTING A SMART IDENTITY FOR FARIDABAD CITY.
- Yunus, P.M., Kargi, F., 2009. Removal of Cu (II) ions by biosorption onto powdered waste sludge (PWS) prior to biological treatment in an activated sludge unit: a statistical design approach. Bioresour. Technol. 100, 2348–2354.

MANAV RACHNA
Vidyaparivar

Dr. O.P. Bhalla Central Library
Manav Rachna International Institute of Research and Studies
(A deemed-to-be-university under section 3 of UGC Act 1956)

SIMILARITY VERIFICATION CERTIFICATE

Title: ...QUALITY ASSESSMENT OF DRINKING WATER IN FARIDABAD ...CITY AND APPLICATION OF BIOSORPTION TECHNOLOGY FOR REMOVAL OF HEAVY METAL CADMIUM IN WATER

Researcher:..Ms. MEHAK VERMA Registration Number:.....18/Ph.D/077

Supervisor:..Dr. SARITA SACHDEVA Department:...DEPARTMENT OF BIOTECHNOLOGY

This is to certify that the above mentioned Short Synopsis/~~Thesis~~ was scanned for similarity index through Turnitin Software on..6.06.22..with submission ID 1851699896 and the similarity index was found to be....10.....%.The complete report running into 24..Pages, ..5926..Word count with File Size..3665..KB is being forwarded to the Research Supervisor/DRC/DRB for review.

Date: 7.06.2022

Dr. O.P. BHALLA CENTRAL LIBRARY
7612
MRIIRS Faridabad

The complete report of the above Short Synopsis/Thesis has been reviewed and the similarity index is below the accepted norms as per the University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018. The Short Synopsis/Thesis may be considered for further processing

Mehak
Research Scholar

6/6/22
Research Supervisor

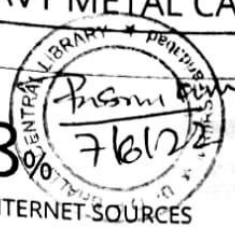
QUALITY ASSESSMENT OF DRINKING WATER IN FARIDABAD CITY AND APPLICATION OF BIOSORPTION TECHNOLOGY FOR REMOVAL OF HEAVY METAL CADMIUM IN WATER

by Mehak Verma

Submission date: 06-Jun-2022 11:09PM (UTC+0530)
Submission ID: 1851699896
File name: PTION_TECHNOLOGY_FOR_REMOVAL_OF_HEAVY_METAL_CADMIUM_IN_WATER.doc (291.5K)
Word count: 5926
Character count: 33388

QUALITY ASSESSMENT OF DRINKING WATER IN FARIDABAD CITY AND APPLICATION OF BIOSORPTION TECHNOLOGY FOR REMOVAL OF HEAVY METAL CADMIUM IN WATER

ORIGINALITY REPORT



10%	8%	Excluding matches less than 14 words 8%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	dns2.asia.edu.tw Internet Source	1%
2	docplayer.net Internet Source	1%
3	cyberleninka.org Internet Source	1%
4	Submitted to RICS School of Built Environment, Amity University Student Paper	1%
5	link.springer.com Internet Source	1%
6	cedadocs.ceda.ac.uk Internet Source	1%
7	"Biosorption for Wastewater Contaminants", Wiley, 2022 Publication	1%
8	ujcontent.uj.ac.za Internet Source	1%

9	Univendspace.univen.ac.za Internet Source	<1 %
10	www.scribd.com Internet Source	<1 %
11	Experientia Supplementum, 2012. Publication	<1 %
12	www.mysciencework.com Internet Source	<1 %
13	"Groundwater Geochemistry", Wiley, 2021 Publication	<1 %
14	Arif Ahamad, N. Janardhana Raju, Sughosh Madhav, A. H. Khan. "Trace elements contamination in groundwater and associated human health risk in the industrial region of southern Sonbhadra, Uttar Pradesh, India", Environmental Geochemistry and Health, 2020 Publication	<1 %
15	Chowdhury, Shakhawat, M.A. Jafar Mazumder, Omar Al-Attas, and Tahir Husain. "Heavy metals in drinking water: Occurrences, implications, and future needs in developing countries", The Science of The Total Environment, 2016. Publication	<1 %
16	Submitted to Cranfield University	

Student Paper

<1%

17 V Rao, M Rao, M Krishna. "Physico Chemical Assessment and Comparison of Quality of Underground Water for Drinking Purpose at Periodic Interval in the Village of Srikurmam, Gara Mandal in Srikakulam District, Andhra Pradesh, India", Current World Environment, 2014 <1%
Publication

Exclude quotes	On	Exclude matches	< 14 words
Exclude bibliography	On		